

THANK YOU, LADIES [?] AND GENTLEMEN :

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IT IS A GREAT PLEASURE FOR ME TO BE INVITED HERE TODAY. A QUARTER OF A CENTURY AGO, I VISITED BOMBAY AFTER MY LUNAR FLIGHT AND THIS CITY GAVE ~~US~~ A WONDERFUL WELCOME. I WILL NEVER FORGET IT.

A FEW YEARS AGO, I WAS IN PARIS DELIVERING A PAPER ON RESEARCH. I OPENED THE PAPER WITH AN OLD CHINESE PROVERB. AFTER THE SESSION, I WAS APPROACHED BY THE PERMANENT SECRETARY OF THE FRENCH ACADEMY WHO WAS IN THE AUDIENCE. HE INFORMED ME THAT THE QUOTE WAS NOT CHINESE AT ALL, BUT GREEK. SPECIFICALLY, ANTISTEHNES IN THE THIRD CENTURY BC. THE LESSON WAS: NO MATTER WHAT THE SUBJECT OF A LECTURE, SOMEONE IN THE AUDIENCE WILL KNOW MORE ABOUT IT THAN THE SPEAKER:-

I HAVE FOUND THAT EVEN IN TALKING ABOUT SPACE FLIGHT, I WILL MEET PEOPLE WHO ARE MORE KNOWLEDGEABLE THAN I. BUT THEY ARE USUALLY 10 OR 12 YEARS OLD, SO I MAY BE SAFE TODAY. WHEN I WAS A LAD, THERE WERE NO ROCKETS, NOT EVEN JET AIRPLANES. AIRCRAFT COULD NOT FLY SUPERSONICALLY. INDEED, MANY EXPERTS BELIEVED THAT IT WAS TECHNICALLY IMPOSSIBLE.

AND ALTHOUGH WE DREAMED OF JOURNEYING THROUGH THE HEAVENS TO FAR-AWAY PLANETS -- WE RECOGNIZED THAT THEY WERE, IN FACT, JUST DREAMS -- AND HARBORED NO ILLUSIONS THAT SUCH VOYAGES WOULD ACTUALLY OCCUR -- CERTAINLY NOT IN OUR LIFETIMES. BY THE TIME I HAD BECOME A YOUNG MAN, JETS, ROCKETS, AND SUPERSONIC FLIGHT HAD BECOME A REALITY. BUT SPACE FLIGHT -- NO, THAT REMAINED AS REMOTE AS EVER.

BUT ABOUT 1952, THE ROCKET PIONEER, DR. WERNER VON BRAUN, WROTE A BOOK WITH A BOLD PREMISE. VON BRAUN SUGGESTED THAT ALL THE COUNTRIES OF THE WORLD POOL THEIR RESOURCES AND JOIN AN INTERNATIONAL ENTERPRISE TO SEND A MANNED EXPEDITION TO THE MOON. HE PREDICTED THAT.....WITH ALL THE COUNTRIES COMMITTED TO THE SUCCESS OF THE PROJECT, SUCH A GOAL COULD INDEED BE REACHED.....BY THE YEAR 2000.

AS A YOUNG ENGINEER AND JET PILOT, I WAS REALLY IMPRESSED BY THAT BOOK. WELL, ACTUALLY, I DIDN'T BUY THE BOOK, BUT I HAD READ THE CONDENSATION IN A POPULAR MAGAZINE. BUT CANDIDLY, I TOO, REGARDED THE PROPOSED TIME TABLE -- THE YEAR 2000- WITH SUBSTANTIAL SKEPTICISM.

NO MAN-MADE OBJECT HAD EVER BEEN PUT INTO ORBIT. THE ONLY KNOWN METHOD OF GETTING THERE WAS THE ROCKET -- AND ROCKETS IN THOSE DAYS WERE NOTORIOUS -- BLOWING UP MORE OFTEN THAN THEY FLEW. THE FASTEST EXPERIMENTAL AIRCRAFT HAD REACHED LESS THAN 10% OF THE SPEED NECESSARY FOR SUCH A TRIP. AND TO HAVE ALL THE COUNTRIES OF THE WORLD COOPERATE ?? HARDLY LIKELY.

THE SEED THAT ACTUALLY SPROUTED THE SPACE AGE WAS THE INTERNATIONAL GEOPHYSICAL YEAR, OR IGY. 66 COUNTRIES JOINED TOGETHER IN A MULTI-DIMENSIONAL ANALYSIS OF THE PLANET EARTH -- OCEANOGRAPHY, METEOROLOGY, SOLAR ACTIVITY, THE EARTH'S MAGNETISM, THE UPPER ATMOSPHERE, COSMIC RAYS, METEORS -- ALL VERY ESOTERIC ~~SECT~~ TO MOST OF US.

THE INTERNATIONAL GEOPHYSICAL YEAR LASTED FROM JULY 1, 1957 TO DECEMBER 31, 1958 -- IT WAS A REALLY THE INTL GEOPHYSICAL YEAR AND A HALF. --THAT PARTICULAR TIME WAS SELECTED BECAUSE IT WAS THE TIME OF MAXIMUM SUNSPOT ACTIVITY. -- AND ALL KINDS OF PHENOMENA SEEMED TO BE SOMEHOW RELATED TO SUNSPOTS.

BOTH RUSSIAN & AMERICAN SCIENTISTS RECOGNIZED THAT IF THEY COULD USE A ROCKET TO PUT AN ARTIFICIAL SATELLITE UP INTO ORBIT AROUND THE EARTH - CARRYING SOME SCIENTIFIC INSTRUMENTS, IT MIGHT COLLECT SOME GENUINE 'BREAKTHROUGH' INFORMATION. THEY DID NOT RECOGNIZE IT AT THE TIME, BUT THEY HAD STARTED A NEW COMPETITION WHICH WOULD BECOME KNOWN AS-- THE SPACE RACE. THE RUSSIANS WON THE GOLD AND SILVER WITH SPUTNIK 1 & 2 WHILE THE AMERICANS FIRST TRY FIZZLED, WHICH GAVE THE WAGS A LOT OF FUN -- THEY CALLED IT KAPUTNIK. BUT THE AMERICANS FINALLY WON A BRONZE WITH EXPLORER 1.

BOTH THE RUSSSIANS AND THE AMERICANS WERE OBSESSED WITH GETTING A MAN IN SPACE. NEITHER WAS CERTAIN WHAT TYPE OF PERSON COULD BE PERSUADED TO TAKE THE TRIP. PRISONERS WERE SUGGESTED -- AND SOLDIERS COULD BE ORDERED. PHYSICIANS WERE POSSIBILITIES. FINALLY BOTH COUNTRIES USED PILOTS -- THEY WERE ACCUSTOMED TO BEING CLOSED UP IN SMALL SPACES, AND ACTUALLY SEEMED TO ENJOY BEING AWAY FROM THE EARTH'S SURFACE.

THE ONLY REASON BIG ROCKETS WERE DEVELOPED WAS TO SEND NUCLEAR WARHEADS ACROSS OCEANS. SO, BOTH COUNTRIES WOULD TRY TO USE THEIR BIGGEST MILITARY BALLISTIC MISSILE ROCKETS TO THROW A MAN INTO SPACE FIRST. AGAIN, THE RUSSIANS WON THE GOLD WITH YURI GAGARIN -- THE SILVER WITH GHERMAN TITOV - - AND THE AMERICANS AGAIN SETTLED FOR A BRONZE .

BY THE END OF THE FIRST DECADE OF THE SPACE AGE, AMERICANS WERE FLYING THE GEMINI -- A TWO MAN CRAFT WITH PROPULSION THAT WOULD PERMIT CHANGING ORBITS, AND WITH ON-BOARD NAVIGATION AND GUIDANCE THAT ALLOWED RENDEZVOUSING BETWEEN SPACECRAFT AND STEERING WHILE ENTERING THE ATMOSPHERE.

THE GEMINI WAS A WONDERFUL LITTLE MACHINE. USING IT, I WAS ABLE TO RENDEZVOUS WITH AN UNMANNED SPACE SHIP -- AND MAKE THE FIRST SPACECRAFT DOCKING IN HISTORY. I ALSO SET ANOTHER RECORD ON THAT FLIGHT.

IN THOSE DAYS, WE LANDED IN THE OCEAN BY PARACHUTE -- CANDIDLY, IT WAS NOT A PARTICULARLY ELEGANT ARRIVAL -- AND HOPED THERE WOULD BE A SHIP NEARBY TO PICK US UP . WE TOOK GREAT PRIDE IN LANDING CLOSE TO THE AIRCRAFT CARRIER AWAITING US. MY AIRCRAFT CARRIER WAS LOCATED IN THE CARRIBEAN. -- I LANDED NEAR OKINAWA. IT WAS THE FURTHEST ANYONE HAS EVER MISSED -- --AND I DON'T EXPECT THE RECORD TO BE BROKEN.

AS PLANNING FOR THE APOLLO PROGRAM BEGAN, MORE THAN 10,000 SEPARATE TASKS WERE IDENTIFIED THAT HAD TO BE ACCOMPLISHED FOR A SUCCESSFUL LUNAR FLIGHT. EACH TASK HAD SPECIFIC OBJECTIVES, MANPOWER REQUIREMENTS, TIME SCHEDULES AND INTERRELATIONSHIPS WITH OTHER TASKS. IT WAS SAID THAT WE COULD HAVE CLIMBED ALL THE WAY TO THE MOON ON THE STACK OF PAPER THAT WE CREATED IN THE PROJECT.

WHICH HAD TO BE DONE FIRST? WHICH COULD BE DONE CONCURRENTLY? WHICH WERE THE CRITICAL SEQUENCES? APOLLO, OF COURSE, WAS A GOVERNMENT PROJECT. HENCE IT WAS POLITICAL. IT WAS RESPONSIBLE TO MANY CONSTITUENCIES. ~~IT WAS ALSO AN ENORMOUS PROJECT. WIDELY DISPERSED PROJECT.~~

~~THAT'S GOOD NEWS AND BAD NEWS. THE GOOD NEWS WAS THAT RESEARCH, DEVELOPMENT AND MANUFACTURING COULD BE APPORTIONED TO ALL REGIONS OF THE COUNTRY. THE BAD NEWS WAS THAT IT WAS APPORTIONED TO ALL REGIONS OF THE COUNTRY. THAT BROAD PARTICIPATION ENGENDERED WIDESPREAD POPULAR SUPPORT, BUT THE MANAGEMENT CHALLENGES FOR SUCH A WIDELY DISPERSED ENTERPRISE WERE ENORMOUS.~~

EVERY BUSINESS INCLUDES SUBSTANTIAL PLANNING, WHICH INVOLVES DEALING WITH THE FUTURE. BUT NONE OF US ARE PARTICULARLY GOOD AT KNOWING WHAT CHALLENGES TOMORROW WILL BRING.

AFTER THE LAUNCH OF SPUTNIK, THE FAMOUS SCIENTIST AND INVENTOR , DR. LEE DEFOREST, THE FATHER OF ELECTRONICS, SAID : "THIS YEAR MAY BECOME KNOWN AS THE YEAR OF THE FIRST MAN-MADE PLANET -- THE TINY ARTIFICIAL SATELLITE. BUT TO PLACE A MAN IN A MULTI-STAGE ROCKET AND PROJECT HIM INTO THE CONTROLLING GRAVITATIONAL FIELD OF THE MOON, WHERE THE PASSENGERS CAN MAKE SCIENTIFIC OBSERVATIONS, PERHAPS LAND ALIVE, AND THEN RETURN TO EARTH -- ALL THAT CONSTITUTES A WILD DREAM WORTHY OF JULES VERNE. I AM BOLD ENOUGH TO SAY THAT SUCH A MAN-MADE MOON VOYAGE WILL NEVER OCCUR -- REGARDLESS OF ALL SCIENTIFIC ADVANTAGES."

AND, AS YOU KNOW, EVEN THE ETERNAL OPTIMIST, WERNER VON BRAUN, THOUGHT THE EARLIEST MAN COULD GO TO THE MOON WOULD BE THE YEAR 2000.

SO I THINK YOU CAN UNDERSTAND THAT WHEN.....31 YEARS BEFORE THE YEAR 2000, I FOUND MYSELF -- IN COMMAND OF A SPACECRAFT.....IN ORBIT AROUND THE EARTH.....WITH EVERY INTENTION OF HEADING OFF TO THE MOON,.....I WAS MORE THAN JUST A LITTLE AMAZED.

AMAZED, NOT ONLY BECAUSE OF THE UNLIKELY CHAIN OF EVENTS AND QUIRKS OF FATE THAT HAD PUT ME.....A ~~REAR~~ FARM BOY.... IN THAT REMARKABLE POSITION.....BUT AMAZED EVEN MORE BECAUSE EVERYTHING IN THE BIG MONSTER IN WHICH WE WERE RIDING.....WAS WORKING!

OUR APOLLO SPACECRAFT, WITH ITS SATURN BOOSTER, HAD 4 MAJOR COMPUTERS, 72 ROCKET ENGINES OF VARIOUS TYPES AND SIZES..... PLUMBING , WIRING, RELAYS, VALVESOVER 5 MILLION COMPONENTS. AND -- AS IS OFTEN QUIPPED, -- 'ALL BUILT BY THE LOWEST BIDDER'.

EVEN IF EVERY PIECE OF THAT HARDWARE MET ITS RELIABILITY SPECIFICATIONS, WE SHOULD REASONABLY EXPECT ABOUT 1000 SEPARATE IDENTIFIABLE EQUIPMENT FAILURES DURING THE COURSE OF EACH FLIGHT. SO, SAFELY IN ORBIT WITH ESSENTIALLY EVERYTHING WORKING, WE WEREN'T CERTAIN WHETHER TO BE HAPPY.....OR SUSPICIOUS.

AS IT HAPPENED, THE HARDWARE WORKED BETTER THAN WE HAD A RIGHT TO EXPECT. FAILURES IN EACH OF THE FLIGHTS WERE MORE LIKE A HUNDRED THAN A THOUSAND.....AN IMPROVEMENT I ATTRIBUTE TO THE DEDICATION OF EVERY INDIVIDUAL WORKING ON THE PROJECT.....THE PERSON ON THE BENCH BUILDING COMPONENTS, THE ASSEMBLERS, THE INSPECTORS, AND INSTALLERS.....EACH PERSON - -DETERMINED TO PROVE THAT THEY WOULD NOT -- THROUGH CARELESSNESS OR APATHY -- BE THE CAUSE OF A FAILURE THAT COULD END IN DISASTER.

I REMEMBER SEEING A CARTOON SHOWING A SPACESHIP MARKED "1995 EXPEDITION". THE VEHICLE WAS PICTURED JOURNEYING OUT TO SOME FAR DISTANT WORLD.....BUT PASSING IT WAS ANOTHER LARGER SPACESHIP, OBVIOUSLY OF MUCH SUPERIOR TECHNOLOGY, MARKED "2010 EXPEDITION". THE CREWMEN IN THE NEWER, FASTER SPACESHIP WERE LEANING OUT YELLING TO THE SLOWER VEHICLE, " IF YOU FELLOWS HAD JUST WAITED A LITTLE LONGER YOU WOULD HAVE GOTTEN THERE SOONER.

UNDOUBTEDLY, IT IS TRUE THAT OFTEN, IF WE WAIT A LITTLE LONGER WE WILL GET THERE SOONER, BUT THE OTHER SIDE OF THAT COIN IS: IF WE WAIT A LITTLE LONGER, WE MIGHT NOT GET THERE AT ALL .

APOLLO 11 REQUIRED A 2-STEP LAUNCH. THE FIRST PART TOOK US INTO ORBIT. MOST OF YOU KNOW THAT OUR ORBITAL SPEED, THE SPEED OF ANY SATELLITE IN LOW EARTH ORBIT, IS ABOUT ~~24K~~ ^{24K} MPH . IN THE SECOND PHASE OF THE LAUNCH, WE NEEDED TO ACCELERATE AN ADDITIONAL ~~8K~~ ^{11K} MPH TO KICK US OUT OF EARTH ORBIT AND TOWARD THE MOON.

FOR OUR PARTICULAR TRAJECTORY, THIS MEANT FIRING UP THE THIRD STAGE OF OUR SATURN ROCKET SOUTHEAST OF HERE, OVER THE INDIAN OCEAN, WHICH HAPPENED TO BE ON THE NIGHT SIDE OF THE EARTH. NOW YOU CAN'T SIT IN ANY KIND OF A MACHINE AND ACCELERATE 11K KPH IN A FEW MINUTES AND NOT KNOW SOMETHING IS GOING ON ! BUT AT NIGHT.....WE JUST COULDN'T GET A VISUAL IMPRESSION OF WHAT WAS HAPPENING.

BUT AS WE FLEW INTO DAYLIGHT OVER INDONESIA, WE COULD SEE.... AND IT WAS OVERWHELMING. WE WERE MOVING OUTWARD FROM EARTH.... BUT FROM OUR VANTAGE POINT, WE SEEMED PERFECTLY MOTIONLESS..... WITH THE PACIFIC JUST DROPPING AWAY FROM US.....AT A RATE OF ABOUT 10000 ^KMPH. MORE AND MORE OF THE HORIZON APPEARED UNTIL EARTH WAS A SPHERE.....A GREAT BLUE MEDICINE BALL FLOATING SLOWLY AWAY FROM US INTO THE INKY BLACK SKY. THAT'S WHEN I WONDERED IF I WAS IN THE RIGHT OCCUPATION.

BUT THE APPREHENSION FADED QUICKLY.....THERE WAS JUST TOO MUCH WORK TO DO. TOO MANY THINGS TO LOOK AT AND BE AMAZED BY. TOO MUCH CONVERSATION...
....NOT JUST AMONG THE CREW, BUT WITH THE FOLKS AT MISSION CONTROL BACK ON EARTH. EVERY FEW MINUTES WE WOULD HEAR : HELLO, APOLLO 11, THIS IS HOUSTON. I DON'T KNOW WHY THEY SAID THAT, WHO ELSE WAS IT GOING TO BE?

STILL, IT WAS NICE TO HEAR THEIR VOICE,.....AND HAVE THEIR EXPERT ADVICE AVAILABLE WHEN YOU NEEDED IT. THERE WAS A PHONE OPEN TO EVERY CONTRACTOR AND MANY SUB-CONTRACTORS. IF THERE WAS ANY QUESTION REGARDING THE OPERATION OF ANY ON-BOARD COMPONENT, MISSION CONTROL COULD USUALLY CONSULT WITH THE PERSON WHO ASSEMBLED THAT PART.

IT WAS A TEAMWORK OPERATION ,AND THE SUCCESS OF THE TEAMWORK WAS RESPONSIBLE FOR THE SUCCESS OF THE PROJECT. OF COURSE, YOU ALREADY KNOW ALL THAT. YOU DIDN'T HAVE TO BE INVOLVED IN APOLLO TO KNOW ABOUT TEAMWORK. IT IS ESSENTIAL TO THE SUCCESS OF EACH OF US.

THE REASON WE FOUND OURSELVES ON THE WAY TO THE MOON WAS A SORT OF POLITICAL ACCIDENT. THE RUSSIANS HAD STARTLED THE WORLD WITH SPUTNIK AND THE FLIGHT OF YURI GAGARIN. IN THE UNITED STATES, WE WERE LEFT AT THE STARTING GATE.

THE NEW AMERICAN PRESIDENT, JOHN KENNEDY, DIDN'T KNOW ANYTHING ABOUT SPACE, AND NEITHER DID HIS CLOSEST ADVISORS, WHO WERE MOSTLY LAWYERS AND POLITICAL SCIENTISTS. AND HE WAS BUSY WITH OTHER THINGS. THE NEW FIDEL CASTRO GOVERNMENT IN CUBA WAS ^{AN IRRITATION TO KENNEDY} ~~A BURR UNDER KENNEDY'S SADDLE~~. AND WHEN U.S. TRAINED REVOLUTIONARIES TRIED TO OVERTHROW CASTRO, KENNEDY TURNED HIS BACK ON THEM.

THE FIASCO WAS KNOWN AS THE 'BAY OF PIGS' – AND IT WAS A POLITICAL DEBACLE. JACK KENNEDY HAD TO FIND A WAY TO GET BACK IN THE GAME. HE HOPED TO FIND ANOTHER AREA TO COMPETE WITH RUSSIA FOR PRESTIGE, BUT COULDN'T FIND ANY. THE WORLD WAS TOO CAUGHT UP WITH THE DAZZLING SUCCESSES IN SPACE.

SO IN A 1962 SPEECH -- HE SAID

"FIRST I BELIEVE THAT THIS NATION SHOULD COMMIT ITSELF TO ACHIEVING THE GOAL, BEFORE THIS DECADE IS OUT, OF LANDING A MAN ON THE MOON AND RETURNING HIM SAFELY TO EARTH. NO SINGLE SPACE PROJECT IN THIS PERIOD WILL BE MORE EXCITING OR MORE IMPRESSIVE TO MANKIND, OR MORE IMPORTANT FOR THE LONG RANGE EXPLORATION OF SPACE, AND NONE WILL BE SO DIFFICULT OR EXPENSIVE TO ACCOMPLISH."

THOSE WERE INSPIRING WORDS -- BUT JACK KENNEDY HADN'T THOUGHT ABOUT -- SUNSPOTS.

TO UNDERSTAND THE IMPORTANCE OF SUNSPOTS, WE'LL HAVE TO GO BACK IN HISTORY -- QUITE A WAY BACK.--- NEARLY FOUR CENTURIES --TO A TOWN IN SOUTHWESTERN HOLLAND MIDDLEBURG.

THE SPECTACLE MAKER OF MIDDLEBURG WAS ONE HANS LIPPERSHEY.

THE STORY IS TOLD THAT ACROSS THE STREET FROM HIS SPECTACLE SHOP WAS A BUTTER AND EGG SHOP. ABOVE THE BUTTER AND EGG SHOP WAS THE BEDCHAMBER OF AN ATTRACTIVE-- AND PROVOCATIVE MILKMAID. THE YOUNG APPRENTICES OF HERR LIPPERSHEY WERE FASCINATED WITH THE MILKMAID AND THE VIEWS THAT COULD OCCASIONALLY BE SEEN THROUGH HER WINDOW.

IT IS IMPRACTICAL TO SPECULATE ON THE CONSEQUENCES OF THIS LIGHT HEARTED LECHERY, BUT IT IS REASONABLE TO ASSUME THAT WITHOUT IT, I WOULD NOT HAVE HEARD OF LIPPERSHEY AND YOU WOULD NOT HAVE HEARD OF ARMSTRONG, AND I WOULD NOT HAVE HAD THE PLEASURE OF BEING INVITED TO BE WITH YOU HERE TODAY.

THE YOUNG APPRENTICES, IN THEIR ZEAL TO IMPROVE THEIR VISION, FOUND THEY COULD ARRANGE SEVERAL LENSES IN SUCH A WAY THAT DISTANT OBJECTS, SUCH AS MILKMAIDS, WHEN VIEWED THROUGH THE APPARATUS, APPEARED AS THOUGH THEY WERE SUBSTANTIALLY CLOSER. AND SO IT HAPPENED THAT THE TELESCOPE WAS BORN

IT WAS JUST AN ODDITY AT THE TIME, AND WAS FIRST MANUFACTURED AS A TOY. NOT TILL THE CONCEPT OF THIS NEW TELESCOPE FOUND ITS WAY ACROSS THE ALPS AND GALILEO GALILEI POINTED HIS VERSION TOWARD THE HEAVENS, WAS IT RECOGNIZED THAT THE HUMAN EYE HAD GAINED AN ENTIRELY NEW PERSPECTIVE ON THE IMMENSITY OF HIS UNIVERSE. GALILEO'S OBSERVATION OF THE MOON REVEALED FACTS THAT COMPLETELY UPSET THE COMMON BELIEFS OF THE TIME.

THE TELESCOPE SHOWED THE MOON IS A SMALLER SISTER PLANET., WITH MOUNTAINS AND VALLEYS. JUPITER ALSO HAD MOONS. THE SUN HAD SPOTS ON ITS SURFACE, SPOTS THAT DISAPPEARED AROUND THE EAST RIM OF THE SUN AND REAPPEARED ON THE WEST RIM. THE SUN WAS A ROTATING BODY!

THE WHOLE CONCEPT OF OUR UNIVERSE WAS WRONG. COPERNICUS, AND HIS CONTENTION THAT THE EARTH WAS NOT THE CENTER OF ALL THINGS MUST BE RIGHT!

THE ROMAN CHURCH GOT SUBSTANTIALLY UPSET WITH GALILEO AND HIS BELIEFS, AND FINALLY HE RECANTED RATHER THAN CHANCE BEING BURNED AT THE STAKE. THE CHURCH WANTED TO HEDGE ITS BETS, HOWEVER, AND STARTED ASTRONOMICAL OBSERVATORIES AT A NUMBER OF ITS MONASTERIES. THEY CHARTED THE SIZE AND FREQUENCY OF THESE SUNSPOTS AND WITHIN THE NEXT CENTURY, IT WAS KNOWN THAT THE SUNSPOTS PEAK IN INTENSITY EVERY 11 YEARS.

BY THE 20 CENTURY, WE KNEW THAT THESE SUNSPOTS PEAKS WERE SINISTER . THEY WERE ACCOMPANIED BY GIGANTIC SOLAR FLARES, PUT OUT ENORMOUS MAGNETIC STORMS AND RADIATION. HERE ON EARTH, WE'RE PROTECTED FROM ALL THESE TROUBLE MAKERS BY THE EARTH'S MAGNETIC FIELD AND ATMOSPHERE. BUT OUT IT SPACE, YOU'RE-- ~~UNPROTECTED AND RUNNING NAKED.~~ *VERY VULNERABLE*

SO WHEN JOHN KENNEDY SAID WE SHOULD GO TO THE MOON BY THE END OF THE DECADE, HE DIDN'T FORESEE THAT SOME POOR SPACEMAN WOULD BE IN FOR A SURPRISE -- THE END OF THE DECADE GOAL WOULD PUT HIM PRECISELY IN THE PEAK OF THE CYCLE!

BUT
WE HAD A CHANCE TO GO TO THE MOON -- AND WE WERE NOT GOING TO LET A FEW SUNSPOTS RUIN OUR TRIP.

SO WE GOT HELP FROM AMATEUR ASTRONOMERS ALL AROUND THE WORLD.
THEY WATCHED FOR SOLAR FLARES. IF THESE SUN GAZERS SAW A BIG STORM ON THE
SUN, THEY WOULD GET ON THE PHONE TO MISSION CONTROL.
AND HOUSTON WOULD CALL UP THE SPACECRAFT: ~~HELLO APOLLO, THIS IS HOUSTON.~~

~~AND THEN WE WERE SUPPOSED TO~~ ^{WOULD} ORIENT OUR SPACECRAFT SO THAT OUR COCKPIT
WAS SHIELDED FROM THE SUN'S RAYS BY OUR FUEL TANKS. THEN HOPE THAT THE FUEL
AND TANKS WOULD ABSORB ENOUGH OF THE RADIATION FOR US TO SURVIVE.

LUCK WAS WITH US. EVEN THOUGH IT WAS THE PEAK OF THE SUNSPOT CYCLE, WE
NEVER HAD A MAJOR FLARE DURING ANY OF THE APOLLO FLIGHTS. AS A MATTER OF
FACT, WE NEVER HAD ANY HIGH RADIATION DOSES ON THE FLIGHTS.

AND SO IT WAS IN THE SUMMER OF 69 THAT OUR CRAFT KNIFED OUTWARD THROUGH
THE PERPETUAL DAYLIGHT OF CISLUNAR SPACE.....THE GREAT VOID BETWEEN EARTH
AND MOON. CONTRARY TO WHAT YOU MIGHT HAVE EXPECTED FROM WATCHING SCIENCE
FICTION FILMS OR TELEVISION --YOU CAN'T INTUITIVELY TELL WHICH WAY YOU ARE
GOING. UNTIL YOU GET RELATIVELY CLOSE TO A PLANET, EVERYTHING APPEARS
COMPLETELY MOTIONLESS--YOUR SPACESHIP - THE STARS - THE EARTH -- THE MOON..

AS WE CLIMBED HIGH AWAY FROM THE EARTH, WE SLOWED DOWN..... THEN CROSSING
THAT INVISIBLE BOUNDARY THAT MARKS THE LUNAR INFLUENCETHE POINT AT
WHICH THE MOON'S GRAVITY IS PULLING MORE STRONGLY THAN THE EARTH'S.....AND
BEGAN TO FALL INWARD TOWARD LUNA.

FALLING INWARD TOWARD THE MOON WAS EVERY BIT AS SPECTACULAR AS OUR
DEPARTURE FROM EARTH. THE LAST SEVERAL THOUSAND MILES TRAVERSED THE
MOON'S SHADOW. FROM OUR POSITION, THE MOON WAS TOTALLY ECLIPSING THE SUN.

WE WERE SEEING THE NIGHT SIDE OF THE MOON, ILLUMINATED BY EARTHLIGHT. SINCE
THE EARTH IS 16 TIMES BIGGER IN AREA AND ALSO MORE REFLECTIVE, EARTHLIGHT IS
ABOUT 81 TIMES BRIGHTER THAN MOONLIGHT HERE ON EARTH.....AND BECAUSE OF
THE OCEANS,THAT REFLECTED LIGHT FROM EARTH IS DECIDEDLY BLUE.

AT OUR DISTANCE, THE MOON NO LONGER LOOKED LIKE A DISC, AS IT DOES HERE ON EARTH.....BUT RATHER IT WAS CLEARLY 3 DIMENSIONAL, A GIANT BLUE BALL WITH CRATERS AND PLAINS AND RIDGES THAT COULD EASILY BE SEEN ON THE EARTH LIT NIGHT.....A GIANT BLUE BALL TOWARD WHICH WE WERE FALLING FASTER AND FASTER. I THINK IT IS THE MOST SPECTACULAR SIGHT I'VE EVER SEEN.

AS WE REACHED 100 MILES ABOVE THE MOON , WE WOULD IGNITE OUR ENGINE TO ALTER OUR TRAJECTORY INTO AN ORBIT AROUND THE MOON. UNFORTUNATELY, AS IT TURNS OUT, THIS ROCKET FIRING MUST BE PERFORMED ON THE FAR SIDE OF THE MOON - - WHERE EARTH-BASED RADARS CAN'T SEE YOU AND MISSION CONTROL CAN'T TALK TO YOU.

GETTING THE ROCKET ENGINE POINTED IN THE RIGHT DIRECTION FOR THIS MANEUVER PROHIBITED US FROM SEEING THE MOON AS WE APPROACHED -- WHICH WAS PROBABLY A GOOD THING - IF WE WERE OFF IN OUR NAVIGATION BY A TEENY TINY FRACTION, WE WERE GOING TO HAVE A NEW LUNAR CRATER NAMED AFTER US.

AND THE DESCENT AHEAD WOULD CERTAINLY BE THE MOST COMPLEX , THE MOST DEMANDING.....AND THE MOST DANGEROUS PART OF THE FLIGHT. THE UNKNOWN'S WERE NUMEROUS, THE SYSTEMS WERE HEAVILY LOADED, AND THE MARGIN OF SAFETY WAS SLIM. NONE OF THE PARTS AHEAD HAD EVER BEEN TRIED BEFORE.

WELL, AS YOU KNOW, IT ALL WORKED OUT ALL RIGHT. OUR COMPUTER ACTED UP, AND WE HAD USED ALMOST ALL THE FUEL WE HAD, THE DUST KICKED UP BY OUR ENGINE EXHAUST MADE VISIBILITY MARGINAL, BUT, IN THE END, THE EAGLE LANDED LIKE A FEATHER.

IT WAS A MOMENT OF SUPREME SATISFACTION.....THAT INSTANT OF REACHING A GOAL THAT A THIRD OF A MILLION PEOPLE HAD SPENT A DECADE TO ACHIEVE. WE DID HAVE ONE PROBLEM; WE WERE LOST. NOT THAT IT MATTERED ALL THAT MUCH.....

WHEN THE ^{FOUNDS} ~~ROCKET~~ PHYSICIST, EDWARD TELLER, WAS ASKED WHAT THE AMERICANS WOULD FIND WHEN THEY GOT TO THE MOON.....HE SAID: RUSSIANS.

WE DIDN'T EXPECT RUSSIANS, OR ANYBODY ELSE, BUT I SUPPOSE I WAS HOPING TO SEE SOMETHING I RECOGNIZED: A CACTUS, ANIMAL TRACKS..... OR A EMPTY COCA COLA CAN.

BUT IT WAS NOT TO BE. WE WERE ON A STARK DESERT OF ROCK AND SAND. A PLACE NEVER BEFORE VISITED BY MAN.....PROBABLY NEVER KNOWN TO ANY OTHER LIVING THING. I DON'T HAVE TO TELL YOU THAT IT WAS AN EERIE, YET PARTICULARLY SATISFYING EXPERIENCE.

IT WAS A MOMENT OF SUPREME SATISFACTION.....THAT INSTANT OF REACHING A GOAL THAT A THIRD OF A MILLION PEOPLE HAD SPENT A DECADE TO ACHIEVE. AND WE WEREN'T SINKING INTO THE DUST.

WE SPENT 2 1/2 HOURS OUTSIDE EXPLORING THE SURFACE. THE TEMPERATURE OF THE SURFACE WAS MORE THAN 100 CELSIUS, BUT INSIDE THE BULKY SUITS, IT WAS COMFORTABLE. WE COLLECTED SAMPLES OF THE ROCKS, INSTALLED EQUIPMENT TO MEASURE MOONQUAKES & COLLECT PARTICLES FROM THE SOLAR WIND, AND ~~REFLECT LASER BEAMS BACK TO EARTH~~

THE LUNAR GRAVITY IS ONLY 1/6 TH OF EARTH AND IS MOST PLEASANT. I PREFER IT TO HERE ON EARTH. MAN ADAPTS VERY WELL TO IT AND WALKING AND WORKING ARE EASILY ACCOMPLISHED.

MANY OF YOU SHARED OUR FIRST LUNAR EXPLORATION BY WAY OF ~~TELEVISION~~. ~~SOME COUNTRIES WERE ABLE TO WATCH IT ON TELEVISION.~~ ~~SUCCESSFUL TV TRANSMISSION WAS A GREAT SURPRISE TO US. WE HAD NEVER BEEN ABLE TO GET A DECENT PICTURE IN ALL OUR TESTING BEFORE FLIGHT.~~ IN THE MANY FICTIONAL STORIES OF FLIGHT TO THE MOON -- BY JULES VERNE, H. G. WELLS, AND OTHERS, NOT ONE HAD FORECAST THE ABILITY OF THE LUNAR EXPLORERS TO COMMUNICATE WITH EARTH, AND CERTAINLY NONE FORESAW THE PEOPLE OF EARTH SHARING THE ADVENTURE ON ~~TELEVISION~~. RADIO OR TELEVISION.

WE PERFORMED AN EXPERIMENT ON THE LUNAR SURFACE OF WHICH YOU MAY NOT HAVE HEARD. THE IDEA WAS DECEPTIVELY SIMPLE : COMPUTE THE DISTANCE BETWEEN THE EARTH AND THE MOON BASED ON THE TIME IT WOULD TAKE FOR A BEAM OF LIGHT TO TRAVEL UP TO A MIRROR LOCATED ON THE SURFACE OF THE MOON --- AND BE REFLECTED BACK TO EARTH. MY JOB WAS TO INSTALL THE MIRROR.

MIRRORS HAD ALWAYS PUZZLED ME AS A BOY. I COULDN'T UNDERSTAND HOW MY REFLECTION COULD BE BEHIND THE MIRROR --- AND MY RIGHT HAND SEEMED TO BE MY LEFT HAND. IF A MIRROR EXCHANGED RIGHT AND LEFT, WHY DIDN'T EXCHANGE TOP AND BOTTOM ?

AFTER COLLECTING SOME PRELIMINARY ROCK SAMPLES, I SET ABOUT THE JOB OF UNLOADING THE MIRROR. ACTUALLY, THERE WERE MORE THAN ONE -- ONE HUNDRED TO BE PRECISE -- A MATCHED SET. THEY WERE, MORE SPECIFICALLY, QUARTZ CORNER REFLECTORS, BASICALLY ~~THE SAME AS~~ ^{SIMILAR TO} THE REFLECTORS THAT ARE USED IN THOSE TRAFFIC SIGNS THAT SHINE SO BRIGHTLY WHEN THEY ARE ILLUMINATED BY ~~YOUR~~ AUTOMOBILE HEADLIGHTS. THESE MIRRORS HAVE A WONDERFUL CHARACTERISTIC. THEY NOT ONLY EXCHANGE LEFT AND RIGHT, THEY ALSO EXCHANGE TOP AND BOTTOM !

NOW THIS EXPERIMENT IS POSSIBLE ONLY BECAUSE OF A QUIRK OF NATURE -- AN ASTRONOMICAL PECULIARITY. MANY OF YOU WILL REMEMBER THAT, ON THE MOON'S SURFACE, THE DAY IS TWO EARTH WEEKS LONG; A DAY AND A NIGHT : 4 WEEKS. THAT IS, IT TAKES OVER 300 HOURS FOR THE SUN TO RISE IN THE EAST, CROSS THE SKY AND SET IN THE WEST --- BUT THE EARTH -- DOESN'T RISE AND SET AT ALL. IT JUST STAYS FIXED IN APPROXIMATELY ONE SPOT IN THE SKY - CONTINUALLY.

FROM THE SEA OF TRANQUILITY, THE EARTH HUNG ABOVE ME 23 DEGREES WEST OF THE ZENITH - AN AQUAMARINE AND TURQUOISE PENDANT AGAINST A BLACK VELVET SKY. AND IF I COULD GET THE MIRRORS POINTED AT IT, THEY WOULD ALWAYS STAY POINTED CORRECTLY -- OR UNTIL SOMEONE CAME ALONG AND MOVED THE MIRRORS -- OR SOMEONE MOVED THE EARTH.

THE LIGHT THAT WAS PLANNED TO BE SENT UP FROM EARTH WAS A LASER BEAM. THE TIMING OF THE BEAM'S RETURN TO EARTH WOULD BE RECORDED BY AN ULTRA - ACCURATE ELECTRONIC CLOCK.

THE THEORY PROPOUNDS THAT THE MEASUREMENT WOULD YIELD THE DISTANCE TO AND ACCURACY OF BETTER THAN 30 CENTIMETERS. IT MAY NOT BE OBVIOUS WHY ANYONE WOULD WANT TO KNOW THE DISTANCE TO THE SEA OF TRANQUILITY WITHIN 30 CENTIMETERS -- BUT ^{WE} ~~WHEN~~ HAD TO HAVE SOME WAY OF CONFIRMING OUR TRAVEL DISTANCE FOR OUR EXPENSE ACCOUNT.

AS SOON AS THE MIRRORS WERE ALIGNED, THE EXPERIMENT WAS INITIATED AT LICK OBSERVATORY ON TOP OF MT. HAMILTON NEAR SAN FRANCISCO. THE SCIENTISTS SHOT A LASER PULSE TOWARD THE MOON. THEY DIDN'T EVEN WAIT FOR ME TO TAKE COVER.

THOSE SCIENTISTS DOWN ON MT. HAMILTON WERE REALLY EXCITED WITH THIS EXPERIMENT. THAT LASER PULSE WAS PRECIOUS TO THEM. SO WHEN IT DIDN'T GET BACK HOME TO EARTH, THEY WERE REALLY WORRIED. SO THEY SENT UP ANOTHER PULSE --- AND ANOTHER. THEY LOST A LOT OF PULSES THAT NIGHT.

THEY CHECKED THE BIG TELESCOPE THEY WERE USING TO TRY TO CATCH THE RETURNING LIGHT AND ADJUSTED THEIR EQUIPMENT. FINALLY, -- SUCCESS -- A PULSE RETURNED. A FEW MORE ADJUSTMENTS -- AND THEY BEGAN TO CATCH MORE AND MORE OF THE LITTLE FELLOWS.

THE PROBLEM HAD BEEN THEIR USE -- IN THE COMPUTATION -- OF THE **WRONG** LATITUDE AND LONGITUDE OF THE OBSERVATORY, THE SAME WRONG LATITUDE AND LONGITUDE THAT HAD BEEN BELIEVED TO BE CORRECT SINCE ITS CONSTRUCTION IN 1888. SO THE FIRST RESULT FROM THE SET OF MIRRORS ON THE MOON WAS FINDING THE TRUE POSITION OF MT. HAMILTON ON EARTH.

NOW ONE WOULD THINK THAT ONCE THEY FOUND OUT HOW FAR IT WAS FROM MT. HAMILTON TO TRANQUILITY BASE, THEY WOULD BE SATISFIED. NOT SO. NOW THEY WANTED TO FIND OUT HOW THAT DISTANCE CHANGES OVER THE MONTHS AND YEARS, SUPPOSEDLY IMPROVING OUR KNOWLEDGE OF THE MOON'S ORBITAL MOTION ABOUT THE EARTH.

IF THAT WEREN'T ENOUGH, ASTRONOMERS AT PIC-DU-MIDI IN FRANCE FIRED THEIR LASER AT MY MIRRORS. SOON, SCIENTISTS FROM AROUND THE WORLD WERE TRYING THE EXPERIMENT. IT SEEMED EVERYONE WANTED TO FIND OUT HOW FAR THEY WERE FROM THE MOON.

THE PHYSICISTS MAINTAIN THAT HAVING MEASUREMENTS TO THE MOON FROM 2 DIFFERENT PLACES, ALLOWS YOU , WITH THE HELP OF GEOMETRY, TO COMPUTE THE DISTANCE BETWEEN THOSE TWO PLACES - WITHIN 30 CENTIMETERS.

I HAVE NEVER HAD AN PARTICULAR FASCINATION FOR THE DISTANCE BETWEEN MT. HAMILTON AND PIC DU MIDI, BUT I'LL ALLOW THAT IT WOULD BE INTERESTING TO FIND OUT IF THAT DISTANCE IS CHANGING.

YOU MAY REMEMBER THE THEORY THAT STATES THAT EUROPE, AFRICA AND THE AMERICAS WERE ORIGINALLY ONE SOLID LAND MASS. SOME YEARS BACK, THEY SPLIT AND HAVE STEADILY BEEN DRIFTING APART EVER SINCE. IT'S CALLED THE CONTINENTAL DRIFT THEORY.

WHEN YOU LOOK AT THE GLOBE, IT DOES LOOK AS IF YOU COULD SLIDE THE AMERICAS RIGHT ACROSS THE ATLANTIC AND THEY WOULD FIT THE WESTERN SHORE LINE OF EUROPE AND AFRICA. NOW , WITH OUR MIRRORS HAVING BEEN IN OPERATION FOR MORE THAN A QUARTER OF A CENTURY, WE ARE BEGINNING TO GET AN ACCURATE MEASURE OF THIS DRIFT. GEOPHYSICISTS BELIEVE IT WILL BE CRITICAL TO THE UNDERSTANDING OF THE EARTH'S CRUSTAL MOTIONS, THE PRIMARY CAUSE OF CATASTROPHIC EARTHQUAKES.

SO HERE WE ARE -- A QUARTER OF A CENTURY AFTER APOLLO -- AND THE CHANGE HAS BEEN EXTRAORDINARY -- OR PERHAPS THE EXTRAORDINARY HAS BECOME ORDINARY -- IN ANY CASE, CHANGE CONTINUES AT A BREAKNECK PACE.

THE SOVIET EMPIRE HAS DISINTEGRATED, ^{ASIA}~~THE PACIFIC RIM~~ HAS BECOME A FINANCIAL AND INDUSTRIAL POWERHOUSE, THE THREAT OF MASS DESTRUCTION HAS LARGELY DISAPPEARED, ONLY TO BE REPLACED BY A SEEMINGLY EVER INCREASING NUMBER OF REGIONAL CONFLICTS.

PERSONAL COMPUTERS - WHICH DID NOT EXIST DURING APOLLO-- HAVE CREATED ONE OF THE PLANET'S LARGEST INDUSTRIES, AND SOME OF THE WEALTHIEST ENTREPRENEURS. CELLULAR TELEPHONES ARE ^{EXPANDING}~~COMMONPLACE~~ THROUGHOUT THE ~~WORLD~~ MAJOR CITIES OF THE WORLD.

AT THE SAME TIME, THE WORD 'TECHNOLOGY' CONJURES IMAGES OF CHERNOBYL, THALIDOMIDE, EXXON VALDEZ AND BHOPAL. TECHNOLOGY IS A CREATOR OF PROBLEMS AS WELL AS A PROBLEM SOLVER. THE AUTOMOBILE IS THE TRANSPORTATION OF CHOICE IN MUCH OF THE WORLD -- BUT IS ACCOMPANIED BY A QUARTER MILLION AUTOMOBILE RELATED DEATHS EACH YEAR.

ISAAC NEWTON COULD HAVE WRITTEN HIS LAW --'EVERY ADVANTAGE IS ACCOMPANIED BY AN EQUAL AND OPPOSITE DISADVANTAGE'.

CLEARLY, THE TECHNOLOGISTS MUST BROADEN THEIR FIELD OF VIEW. ENGINEERS AND SCIENTISTS MUST DO MORE TO UNDERSTAND THE CONSEQUENCE OF THEIR ACTIONS. BUT POLICY MAKERS MUST DO MORE TO KNOW THE BENEFITS THAT INVESTMENT IN TECHNOLOGY CAN PROVIDE.

MORE THAN 25 YEARS HAVE PASSED SINCE OUR FIRST EXPLORATION OF THE SURFACE OF THE MOON, AND IT IS NOT AN EASY THING TO TALK ABOUT. THE APOLLO PROGRAM IS AT AN UNCOMFORTABLE AGE, TOO YOUNG TO BE HISTORY, AND TOO OLD TO BE NEWS.

WE CAN SAY -

APOLLO INCREASED OUR KNOWLEDGE OF THE MOON A THOUSAND FOLD AND MORE. BUT PERHAPS THE MOST IMPORTANT CONSEQUENCE OF APOLLO WAS NOT THE MOON AT ALL. AN EXTERNAL PERSPECTIVE GAVE NEW MEANING TO THE PLANET EARTH -- A NEW APPRECIATION OF ITS ISOLATION, ITS FRAGILITY, AND ITS FINITE LIMITS. A NEW APPRECIATION FOR THE NEED TO NURTURE AND CARE FOR THIS BEAUTIFUL PLANET THAT IS OUR HOME

SO THAT IS MY STORY OF APOLLO. AN ERA WE ALL REMEMBER - THE TIME WHEN MEN BROKE THE SHACKLES OF GRAVITY. THE ENGINEERING CHALLENGES WERE IMMENSE. AND THE PROFESSION MET THE CHALLENGE.

IT WAS A SUPERB ADVENTURE -- A TOP PERFORMANCE BY A LARGE GROUP OF DEDICATED INDIVIDUALS. THE OPENING OF A NEW FRONTIER -- A FRONTIER SO VAST THAT A THOUSAND GENERATIONS OF EXPLORERS WILL NOT CONQUER MUCH OF IT. BUT WE WILL TRY . IT IS THE HUMAN DESTINY.